nanoCOPS: Analytical Approach for Estimating the Heating of Bond-wires.

Abstract

An analytic model to estimate the heating of bond-wires within a package is described. The formula involves the essential parameters that define a package. This work has been carried out within the FP7 nanoCOPS project.

Introduction

Bond-wires are commonly used to connect the chip and the pins during device assembling. These wires are heated up due to Joule effects and their temperature. Fig. 37 shows a diagram of a classic IC lead-frame package.

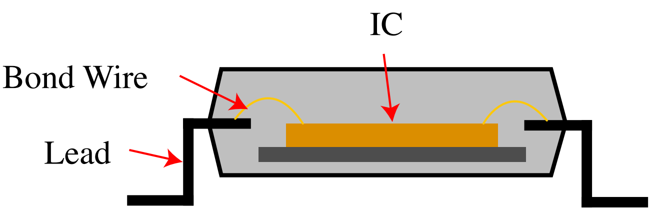

Figure 37: *Classic IC lead-frame package.*

Since wire melting is a potential source of failure in IC devices, one would like to estimate, in a expedient manner, the current amplitude and duration that could cause such a failure. Ideally, the sought formula should involve the most important physical parameters that define the package. In this letter, we briefly describe an analytic bond-wire heating model, offspring of a collaboration between TU-Darmstadt and ON Semiconductor within nanoCOPS, that extends the one in [2].

Analytic Bond-Wire Heating Model

Fig. 38 depicts the simplified thermal problem upon which the model is built.

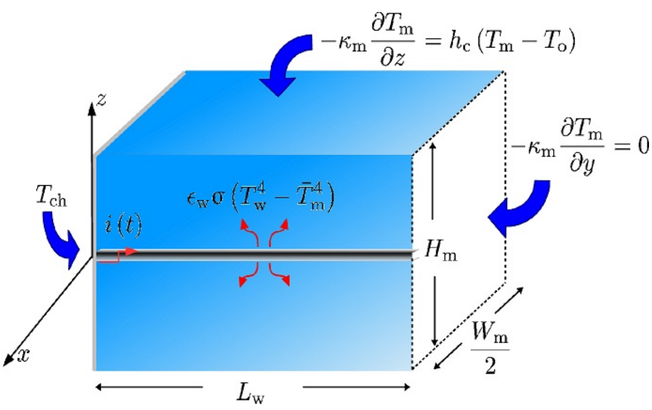

Figure 38: *Bond-wire heat transfer problem.*

The rectangular shape of the package compound is retained and suitable boundary conditions (BCs) are used;

1. adiabatic on the rightmost wall except on the wire portion. This facilitates the inclusion of the lead into the model;
2. iso-thermal on the leftmost and bottom walls amounting to the chip and die-attach temperatures;
3. convective on lateral and upper walls;
4. thermal radiation on the wire surface.

The temperature dependence of the wire thermal and electrical conductivities is also included. The heat equation is solved by means of an *ad-hoc* linearisation which involves the compound heat equation and its heat kernel [1], viz.

$$T_{\rm w}\left(y,t\right) \cong T_{\rm o} + \frac{\sqrt{2\alpha_\kappa\widetilde{\theta}_{\rm w}(y,t)+1}}{\alpha_\kappa} - \frac{1}{\alpha_\kappa}. \qquad (37)$$

Above, $T_{\rm w}$ is the wire temperature, $T_{\rm o}$ is the reference (ambient) temperature, α_κ is the temperature coefficient of the wire thermal conductivity, and $\widetilde{\theta}_{\rm w}$ is an auxiliary variable.

Numerical Results

Several numerical tests for wires of Gold, Copper, and Aluminium have been performed with data provided by ON Semiconductor. Numerical verification has been carried out with CST Multiphysics Studio™, and a good agreement has been corroborated.

Fig. 39 shows the estimated current capacity (temperature vs current amplitude) for a gold wire after 50 ms.

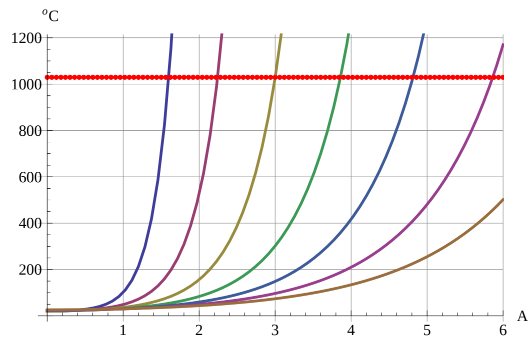

Figure 39: Au-*wire current capacities for diameters* $D_w = \{0.8, 1.0, \ldots, 1.8, 2.0\}$ *mil and* $L_w = 2.5\,\mathrm{mm}$. *The plotted temperature is at the wire mid-point, where the hottest point is expected.*

Conclusions and Further Actions

A transient and fully analytic model for the estimation of the heating of bond-wires within a package has been developed. The model resorts to simple mathematical functions, and retains the most important geometric and physical parameters of the package. The model readily permits to estimate the wire melting current and the mould deterioration current. Currently, an *in-house* numerical implementation is underway at TU Darmstadt, and a measurement setup is in preparation by Brno University of Technology and in collaboration with ON Semiconductor, to supply experimental data, which will permit to further enhance the capabilities of the model.

References

[1] D. Duque, S. Schöps, and A. Wieers. An extended analytical approach for the estimation of the heating of bondwires. In *18th European Conference on Mathematics for Industry (ECMI)*, Taormina, Sicily, Jun. 2014. European Cosortium for Mathematics in Industry.

[2] G.T. Nöbauer and H. Moser. Analytical approach to temperature evaluation in bonding wires and calculation of allowable current. *Advanced Packaging, IEEE Transactions on*, 23(3):426–435, Aug 2000.

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Splitting Methods on Special Meshes

Abstract

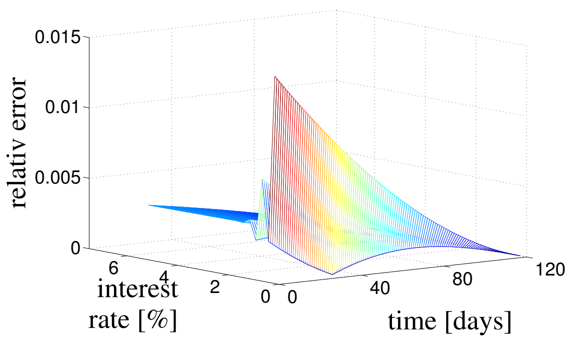
Zuzana Bučková started her position at BU Wuppertal in ITN STRIKE as Early-Stage-Researcher (ESR1) in Sept. 2013. Since this time she has worked under the supervision of Prof. Matthias Ehrhardt and Prof. Michael Günther on the two following tasks:

- Fichera theory and its application in finance.
- ADE methods for the Black-Scholes model.

The aim is to deal with novel finite difference methods for a class of nonlinear Black-Scholes (BS) equations modelling illiquid markets or transaction costs. Numerical analysis of the Alternating Direction Explicit (ADE) method and its application in finance, taking into account Fichera theory, is presented.

Fichera Theory and its Application in Finance

The *Fichera Theory* focuses on the question of appropriate *boundary conditions* (BCs) for parabolic partial differential equations (PDEs) degenerating at the boundary. According to the sign of the *Fichera function* one can separate the outflow or inflow part of the solution at the boundary, i.e. it indicates whether one has to supply a BC at the degenerating boundary. It turned out to be very useful for establishing the well-posedness of initial boundary value problems for parabolic PDEs degenerating at the boundary. In our work we illustrate the application of the Fichera theory to the *Cox-Ingersoll-Ross* (CIR) interest rate model and its generalisation.



Relative error, case with Dirichlet BC

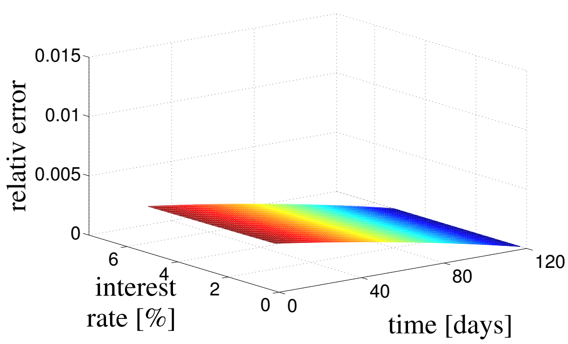


Figure 40: *Relative error, case without BC*